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A New Type of Automatic Monitoring System of Static and Dynamic Displacement on Dam and Slope

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Abstract

It is imperative to explore a type of automatic long-term fixed-point displacement monitoring technology with low cost and high precision in the current monitoring system of dam and slope. The new system obtains information of slope stability through mutual transformation of photoelectric signals which are magnified by a telescope, and it is of strengths of accuracy, timeliness and low cost compared to conventional monitoring instruments, through remote wireless monitoring. In addition, it can also be used to measure the vibration parameters of slope during the blasting. According to the testing and field observations, it has been verified that the system monitored well, without site operations. Therefore, the system may be applied to automatic static and dynamic displacement monitoring for both long-term and short-term without wiring and operations.

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Keywords: Long-distance monitoring, Slope displacement, Photoelectric target

1. Introduction

Because of the complexity of the slope rock mass structure, the real mechanics within a slope are unable to be fully considered from geotechnical investigations to treatment designs. Under the influence of natural factors and the role of various loads, slope work traits vary at any time. In order to reflect the real mechanical effect of the rock mass and to ensure stable state of the slope, a slope monitoring project is needed to be carried out. Nowadays, there are many kinds of domestic and overseas slope safety monitoring technologies and methods, from the traditional total-station, the inclined pipe, the pressure gage, the rainfall plan and the displacement meter to the new type of GPS, the TDR, the laser range finder, and the synthetic aperture radar. They are used plentifully in practical monitoring of engineering, and most of them occur in a manner of integration of several technologies. Traditional approaches are not able to compete with the modern approaches in terms of the automation, digitalization and precision and also waste lots of manpower and material resources. However, the accumulated engineering experience from these conventional approaches may be used in the modern approaches, as a result of the long-term engineering practice, especially in the measuring-point arrangement and data processing. In comparison, new types of monitoring instruments and techniques are more advantageous from a perspective of timeliness and precision.

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Although the total-station has been used for a longer time and developed a better technology and theory gradually, it is not suitable for long-term fixed-point monitoring of the slope because the price of a high-precision tachometer is very high, with the discontinuous monitoring data and repetitive work in the multipoint monitoring; similarly, monitoring systems using GPS-RTK technology are not cost effective and increase the treatment cost of the slope and the risk of destroying instruments, so it is also not suitable for being fixed in dangerous slope; the data from TDR monitoring is difficult to be used to quantify the displacement of monitoring; with the increase of the monitoring distance, the monitoring precision of the laser rangefinder decreases soon, so it is not suitable for point-to-point monitoring of large area at opencast mines; when clinometers are used to obtain data, there is a need to do manual work repeatedly, so it needs more time, manpower and material resources; monitoring slope with synthetic aperture radar is a new monitoring method, it can monitor the change of multipoint displacement within hundreds of meters, and it has advantage of accuracy and timeliness; however, the defect of the method is that the price is too high, a system costing nearly ten million Yuan. The new system discussed in this article has reasonably solved these problems.

2. The structure and theory of the monitoring system

The new system consists of a photoelectric target, an imaging measuring host machine [1], a solar power supply unit, a wireless relay, and a package of software for GPRS transmission and data acquisition analysis. The system uses the photoelectric image method. The host machine has the ability to distinguish movements as few as 0.1mm, so it can perceive the tiny displacement of the photoelectric target. Then the host machine can transmit the data to software through GPRS and obtain the result users need. Now the system is used in monitoring the displacement of dams, slopes, bridges and ports. And it can monitor continuously and have high precision. Meanwhile, its performance is stable, and therefore it is the best choice for quality and security assurance of engineering.

2.1. Data acquisition system

The data acquisition system mainly is composed of an imaging measuring host machine, a multiple lens component telescope and a photoelectric target, as shown in Fig.1. The picture on the left side is a photoelectric target, and the power consumption of the target is small. In the actual monitoring, the target needs large-capacity of lithium batteries. First, the stability information of the slope is transmitted to the photoelectric target that is fixed on the slope surface. Then the telescope host machine can accept the change of displacement, and obtain specific information about the slope displacement.

Fig. 1. The photoelectric target and host machine

- The telephoto lenses

The telephoto lenses comprise two pieces of convex lenses with different focal lengths [2]. Because the telephoto lenses can be conveniently used to install a reticule between the lenses, with various excellent functions [3], now all military telescopes, small telescopes and other professional telescopes have this kind of structure. Fig. 2 shows its principle. The first function of the telephoto lenses is image enlargement, which increases the perspective of distant objects [4] and makes CCD identifying smaller details of angular distance. Thus, the lenses can achieve the purpose of amplification. The second function is the collection of light [5]. It can have light beams collected by objective lens to form an image on CCD. The beam is much thicker than the CCD (The biggest is 1/2 inches), so the CCD can identify the faint objects that are invisible to naked eyes.

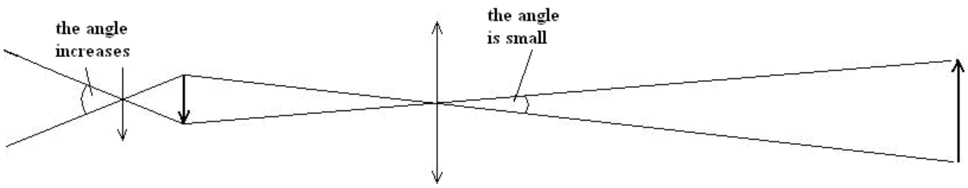

Fig. 2. The principle of the telephoto lenses

- The CCD camera

The CCD camera is made up of a photosensitive unit (Semiconductor image sensor), input structures and output structures [6]. It is an integrative photoelectric transformation device, and its outstanding feature is that it uses charges as the signal carrier. When the incident light illuminates the photosensitive unit, the photosensitive unit will produce photo charges Q[7]. Q is proportional to the photon flow rate ΔN_0, the illumination time T and the area of photosensitive unit A. Equation (1) is shown as follows:

$$Q = \eta q \Delta N_0 AT \tag{1}$$

η—quantum efficiency of the material

q—the quantity of electronic charge

According to the principle above, after comparing the initial conditions with the change of the charge quantity and the position of light-spots, the specific displacement parameters of the slope can be gained [8]. Fig. 3 shows the principle of the imaging measuring host machine. In the actual monitoring, the imaging measuring host machine is fixed at a stable point that is out of the slope [9], and the machine is less than 1,000 m of distance away from the photoelectric target. The photoelectric target and the slope are fixed firmly. The host machine will observe the change of target images' displacement; the optical telescope will transmit the image information of the photoelectric target to the CCD sensor [10]. Through testing the change of the centre coordinate that is on the target [11], the CCD sensor can draw the response curve of vibration and the displacement of the slope on time.

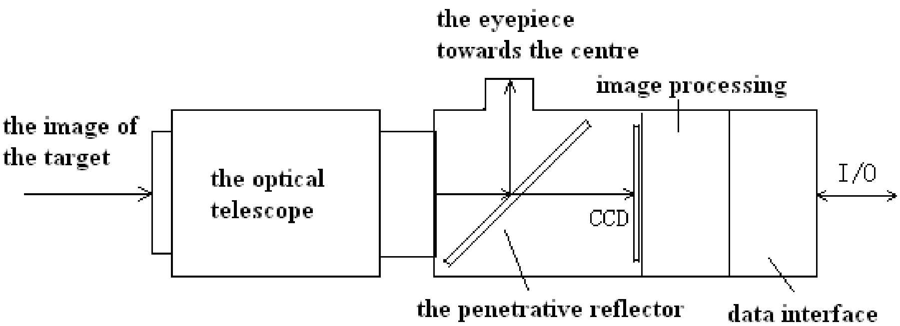

Fig. 3. The principle of the host machine

2.2. data transmission system

The return of the collected data and the sending out of the system control commands need a complete set of data transmission system. Through the GPRS module, the data transmission system makes the data acquisition system connected to the internet [12] and the exchange of data realized. In addition, a point-to-point digital module can be used to transmit the data from the slave station to the master station via the wireless relay, and the monitoring data is transmitted to internet by the GPRS module. Therefore, doing so achieves the wireless transmission of data receiving and commands issuing [13].Fig. 4 shows the data transmission system.

The server is the core part of the whole monitoring system. Its main tasks are receiving or processing of the data and sending of the order. A software package that was particularly developed for the system has been installed to enable remote operations through internet.

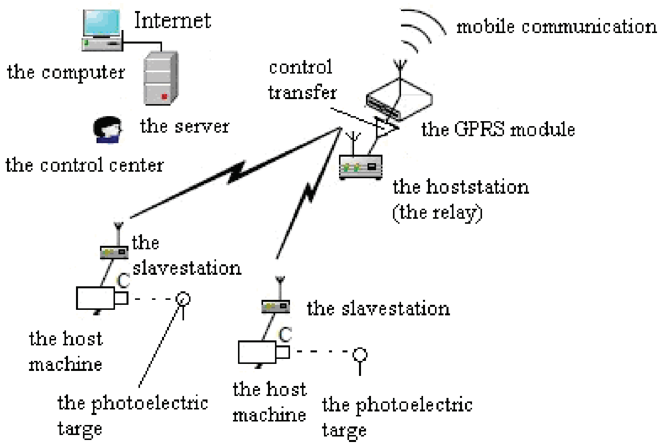

Fig. 4. The data transmission system

The GPRS module is part of the data transmission system of the monitoring system. It transmits in a manner of General Packet Radio Service (GPRS), which is different from the continuous channel transmission, in which the cost, which is paid by users, is calculated by data flow and since it does not always take up the whole channel, it is cheaper in theory. The module is connected with a wireless master station, which can transmit the local signal, and it can write the IP address of the server and port number into the GPRS module, in order to make the module connected to the internet, to find the slave station quickly and to exchange data with servers. On the other hand, information from several slave stations is collected in the cache of the data transmission module and then is transmitted to computers in the control center through the GPRS wireless network, so as to fulfill the data collection and the commands sending [14].

3. The technical indexes

- Enabling measurements in two dimensions at the same time, with measurement range: more than 1m;
- The distance that can be measured (the distance between the host machine and the photoelectric target): 5m~1,000m;
- Frequency response: 0~50Hz（the most is 100Hz）;
- Resolution: measuring distance D×0.2‰mm,（the unit of D is m）;
- Uncertainty: measuring distance D×0.1‰mm,（the unit of D is m）;
- Sampling time: Can be presented on several grades, also can use the way of automatic measurement;
- The wireless transmission distance of host machine: about 1,000m;
- Working temperature: -20℃~40℃;
- Relative humidity: ≤90%; and
- Battery power supply: Can work continuously over three months in the long-term field monitoring.

4. Design and arrangement of measurement points

Every group of observation points consist of a photoelectric target and an imaging measuring host machine. Because the host machine is fastened, one host can correspond to just one photoelectric target and the optical range of two points is not more than 1,000m.

4.1. Design of measurement points

The photoelectric target and the slope surface of measurement points are connected by metal supports with certain strength and stiffness, and the base of metal supports are fastened with the slope rock. Then the plane of the photoelectric target should be kept over against the imaging measuring host machine. Measurement points should be chosen in process of the mining production and the geotechnical survey of the slope and should be positioned at unsafe areas that are tectonic belts and potential sliding bodies found or proved or unsafe areas that have been found in the stability analysis. The representative points that are on the rocks with even and complete surfaces should be found and can be fastened with targets.

When the point of the host machine is chosen, there are lots of conditions that should be considered, such as the rock should be stable enough, without slope displacement and production interferences, the optical range to the photoelectric target should be less than 1,000m, and the displacement monitored should be on the vertical plane of ray axis, which is between the target and the host machine, as well as the displacement should be less than 1m, without direct solar radiation on it (The situation is less on slope monitoring, in which the host machine is always on the top of the slope and the target is on somewhere of the slope, so the host machine always monitors the target from the top downwards).

If host machines are more centralized, as on the both ends of the dam, building a station can be considered, in order to reduce environmental interference, to protect the host machine and to improve the accuracy. Also glass observation windows along the direction of targets can be set.

4.2. Arrangement of measurement points

Based on the monitoring theory and principles above, combined with the shape of the pit, generally the slope displacement is pointed to the centre of the pit. If the pit is nearly round or oval, the ray axis between the target and the host machine should be nearly the tangent of the round pit, that is, the direction of the slope displacement is perpendicular to the observation optical axis and is kept away from the centre of the circle as far as possible, especially in the situation where the horizontal displacement on slippery body is larger than the vertical displacement. The displacement is reflected less obvious in the view of the host machine, so it will influence the sensitivity of observation. Nearly linear dam bodies, such as gravity dams and rock fill dams, the host machine can be considered to be arranged on both ends of the dam.

Measurement points that are used in vibration observations should be kept away from the blasting seismic source as far as possible, trying to be no vibration interference, and the vibration measurement system that consists of a group of vibration sensors should be installed beside the host machine, so it will be convenient to do the vibration analysis for the host machine and to deduct the absolute vibration of the measurement points.

5. Conclusions

Data from the monitoring of slope provides an important basis on the judgment of the slope stability. The monitoring system of the slope is a new exploration for slope monitoring technology, with the main advantages below:

- The monitoring approach can measure micro-deformation of the target within 1,000m and allow multipoint alignment, with higher precision and reliability of long-term monitoring;
- The Industrial Grade of Design of the complete machine is suitable for long-term field monitoring and it overweighs the conventional measuring methods, such as general total-station and theodolite, with the strong expansion ability, low cost of single-point measurement, quick speed, continuous observations, and extensive application range;
- The system is convenient to realize the remote control, and the data can be monitored so long as the system can be connected to internet. The application of the GPRS wireless network transmission is suitable for both the long-term and short-term monitoring observations without requirements of wiring and operator in the field and it are able to analyze trends and effectively issue warnings; and
- According to client needs, the system can be integrated into software with artificial intelligence, such as evaluating measurement results and displaying distortion trends in real time. Based on the advantages above, the static and dynamic automatic monitoring system on dam and slope will be used wider in the field of the engineering monitoring.

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References

[1] Liao J B, Wu M H.,1999. A Coordinate Measuring Machine Vision System, Computers in Industry 36(38), p. 239- 248.
[2] Michael Z, Didier S, U li Bockholt, 2005. AR Telescope - Taking Augmented Reality to a large Audience, Computer Graphik Topics 17(1), p. 19–20.
[3] J. -P. Delaboudinière,G. E. Artzner, et al, 1995. Extreme-Ultraviolet Imaging Telescope for the SOHO Mission, Solar Physics 1, p. 291-312 .
[4] R Weeks,Jr. Infrared Optics and Zoom Lenses. A Publication of SPIE-The International Society for Optical Engineering, Tutorial Texts in Optical Engineering 2, p.42 .
[5] Rendong Nan, 2006.Five Hundred Meter Aperture Spherical Radio Telescope (FAST), Science in China Series G 49(2), p. 129-148.
[6] Kim, Pyunghyun, Rhee, Sehun, 1999.Three Dimensional Inspection of Ball Grid Array Using Laser Vision System, IEEE Transactions on Electronics Packaging Manufacturing 22(2), p. 151-155.
[7] Chang R S, Sheu J Y, Lin C H, Liu H C, 2003. Analysis of CCD Moire Pattern for Micro-range Measurements Using the Wavelet Transform, Optics and Laser Technology 35(1), p. 43- 47.
[8] Murali Subbarao,Ming-Chin Lu,1994. Image Sensing Model and Computer Simulation for CCD Camera Systems, Machine Vision and Applications 7(4), p. 277-289.
[9] Zhang Lin, 2005. Synchronous Error Analysis for TDI-CCD Imaging System Based on MTF," Proceedings of 6th International Symposium on Test and Measurement 7, p. 6173-6176.
[10] Stephane Perrin,Tanneguy Redarce, 1996. CCD Camera Modeling and Simulation, Journal of Intelligent & Robotic Systems 17(3), p. 309-325.
[11] Fischer, T.Radil, 2003. Simple Methods of Edge Position Measurement Using Shadow Projected on CCD Sensor, Measurement Science Review 3(3), p. 37-40.
[12] Charles E. Perkins, 1998. Mobile Networking in the Internet, Mobile Networks and Applications 3(4), pp. 319-334.
[13] Zhang Y S,Boon-Hee, Ma M, 2006. A Dynamic Channel Assignment Scheme for Voice/data Integration in GPRS Networks, Computer Communications 29 (8), p. 1163-1173.
[14] K.Al-Begain, I.Awan, D.D. Kouvatsos, 2003. Analysis of GSM/GPRS Cell with Multiple Data Service Classes, Journal of wireless Personal Communications 25(1), p. 41-57.